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National Eutrophication Survey, Las Vegas, Nev

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Feb 77

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

LAKE WAPPAPELLO

WAYNE AND BUTLER COUNTIES

MISSOURI

EPA REGION VII

WORKING PAPER No. 551

WITH THE COOPERATION OF THE

MISSOURI DEPARTMENT OF NATURAL RESOURCES

AND THE

MISSOURI NATIONAL GUARD

FEBRUARY, 1977

REPORT ON LAKE WAPPAPELLO

WAYNE AND BUTLER COUNTIES, MISSOURI

EPA REGION VII

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Missouri Department of Natural Resources for professional involvement, to the Missouri National Guard for conducting the tributary sampling phase of the Survey, and to those Missouri wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Missouri Department of Natural Resources, James Wilson, Director; the Division of Environmental Quality, Ken Karch, Director; and the Water Quality Program, James Oddendahl, Director, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper series.

Major General Charles M. Kiefner, the Adjutant General of Missouri, and Project Officer Captain Donald L. Wellen, who directed the volunteer efforts of the Missouri National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MISSOURI

LAKE NAME	COUNTY
Clearwater Lake	Reynolds
Pomme de Terre Reservoir	Polk, Hickory
Stockton Reservoir	Dade, Polk, Cedar
Lake Taneycomo	Taney
Thomas Hill Reservoir	Macon, Randolph
Lake Wappapello	Wayne, Butler

LAKE WAPPAPELLO

REPORT ON LAKE WAPPAPELLO, MISSOURI
STORET NO. 2906

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and survey data, Lake Wappapello is considered eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values ranged from 3.0 µg/l in the summer to 14.4 µg/l in the fall, with a mean of 9.6 µg/l. Secchi disc transparency and potential for primary production as measured by algal assay control yields were low. Of the six Missouri lakes sampled in 1974, two had higher median total phosphorus levels, five had higher median inorganic nitrogen values, and four had higher orthophosphorus levels than Lake Wappapello.

Survey limnologists reported floating aquatics (Nymphea) at Station 04 in June, and a heavy algae bloom throughout the open lake with floating algae clumps swept in from side coves at Station 02 in October.

*See Appendix E.

B. Rate-Limiting Nutrient:

The algal assay results indicate phosphorus limitation at the times the assay samples were collected (04/09/74, 10/08/74). Mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 18/1 or greater on all sampling occasions, further indicating primary limitation by phosphorus.

C. Nutrient Controllability:

1. Point sources -

Point sources were estimated to have contributed 1.2% of the total phosphorus load. The city of Annapolis contributed the entire load.

The calculated phosphorus loading of 1.93 g $P/m^2/yr$ for Lake Wappapello is only slightly greater than the eutrophic load proposed by Vollenweider (1975). However, Vollenweider's model may not be applicable for lakes with short hydraulic retention times (14 days for Lake Wappapello), or in which loading calculations yield an apparent net export of phosphorus from the lake. In Lake Wappapello, there are several factors which may account for the apparent export of phosphorus. In addition to the city of Annapolis, there are 25 small private sewage facilities impacting the Wappapello drainage basin (Missouri Department of Natural Resources, manuscript), and several industrial and municipal facilities upstream which are

not included in the nutrient loadings because of their distance from the reservoir. Although the majority of tributaries sampled do not reflect an impact from the smaller private plants in the area, the high background loading to the St. Francis River (Section IV-D) is certainly due, at least in part, to impact from the upstream private, municipal and industrial plants. Among the larger upstream plants are the American Smelter and Refining Company, the Arcadia Meat Processing Company, the Pilot Knob Pellet Company, and municipal sewage treatment facilities for the cities of Ironton, Arcadia, Graniteville, and Middlebrook. There is also a fish hatchery discharging to Hubble Creek, a tributary of the St. Francis River, downstream of the inlet sampling Station A-2. Nutrient contributions from this source are not known. Additional sampling to determine the true nutrient budget for Lake Wappapello is needed before recommendations of nutrient controllability in the lake can be proposed.

2. Nonpoint sources -

The mean annual phosphorus load from nonpoint sources, including precipitation, accounted for 98.8% of the total reaching Lake Wappapello. The St. Francis River contributed 88.8%, and ungaged tributaries were estimated to have contributed 8.0%.

The phosphorus export of tributary C-1, Clark Creek, (Section IV-D) is comparable to the tributary exports of nearby Clearwater Lake (range of 1 to 4 kg P/km^2/yr, mean of 3 kg P/km^2/yr).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry was provided by the Missouri Clean Water Commission. Tributary flow data were provided by the Missouri District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 16.59 km^2.
2. Mean depth: 3.0 meters.
3. Maximum depth: 4.6 meters.
4. Volume: 49,770 x 10^6 m^3.
5. Mean hydraulic retention time: 14 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area(km^2)	Mean flow (m^3/sec)
A-2 St. Francis River	2,432.0	27.56
C-1 Clark Creek	97.1	0.58
Minor tributaries and immediate drainage -	868.5	10.45
Totals	3,377.6	38.61
2. Outlet - A-1 St. Francis River	3,395.5	42.26

C. Precipitation:

1. Year of sampling: 112.4 cm.
2. Mean annual: 111.1 cm.

III. LAKE WATER QUALITY SUMMARY

Lake Wappapello was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from four stations on the lake and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 7.0 meters at Station 01, 11.0 meters at Station 02, 5.5 meters at Station 03, and 9.4 meters at Station 04. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/09/74	1. Melosira	1,539
	2. Chroomonas	503
	3. Nitzschia	403
	4. Cryptomonas	403
	5. Dactylococcopsis	320
	Other genera	835
	Total	4,043
06/10/74	1. Melosira	1,604
	2. Chroomonas	741
	3. Skeletonema	562
	4. Microcystis	472
	5. Dinobryon	336
	Other genera	2,135
	Total	5,930
10/08/74	1. Melosira	3,759
	2. Crucigenia	239
	3. Trachelomonas	239
	4. Ankistrodesmus	179
	5. Cryptomonas	119
	Other genera	177
	Total	4,712

f. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
04/09/74	01	12.4
	02	6.8
	03	9.8
	04	3.6
06/18/74	01	10.0
	02	12.6
	03	3.0
	04	8.9
10/08/74	01	14.4
	02	11.0
	03	9.9
	04	13.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 04/09/74

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
Control	<0.005	0.100	0.1
0.05 P	<0.055	0.100	1.4
0.05 P + 1.0 N	<0.055	1.100	18.5
1.00 N	<0.005	1.100	0.1

b. 10/08/74

Control	0.005	0.294	0.4
0.05 P	0.055	0.294	7.2
0.05 P + 1.0 N	0.055	1.294	9.9
1.00 N	0.005	1.294	0.3

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that potential for primary production was low in Lake Wappapello at the times of sampling. On both sampling dates, increases in yield with the addition of phosphorus as well as the lack of response to the addition of nitrogen indicate phosphorus limitation. Maximum growth potential was achieved with the simultaneous addition of the two nutrients.

Mean N/P ratios in the lake data were 10/1 or greater on all sampling occasions, further indicating primary limitation by phosphorus (a mean N/P of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINS
(See Appendix D for data)

For the determination of nutrient loadings, the Missouri National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when two samples were collected. Sampling was begun in September 1974, and was completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Missouri District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in $kg/km^2/yr$, for Clark Creek at Station C-1, and multiplying the means by the ZZ area in km^2.

Nutrient loads for the city of Annapolis wastewater treatment plant were estimated at 1.134 kg P and 3.401 kg N/capita/yr. Nutrient loads for the city of Greenville (septic tanks, population 328) were estimated at 0.1134 kg P and 4.263 kg N/capita/yr.

A. Waste Sources:

1. Known municipal -

Name	Population Served	Treatment*	Design Flow ($m^3/d \times 10^3$)	Receiving Water
Annapolis	330	Stabilization pond	0.125**	Big Creek

2. Known industrial - See discussion, pages 2-3.

*Missouri Department of Natural Resources, manuscript.
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 St. Francis River	28,305	88.6
C-1 Clark Creek	290	0.9
b. Minor tributaries and immediate drainage (nonpoint load) -	2,545	8.0
c. Known municipal STP's -		
Annapolis	375	1.2
d. Septic tanks* -	40	0.1
Greenville	35	0.1
e. Known industrial - see discussion, pages 2-3.		
f. Direct precipitation** -	290	0.9
Totals	31,960	100.0
2. Output - A-1 St. Francis Riv. -	52,670	
3. Net annual P export*** -	20,710	

*Estimate based on 105 lakeside residences, 2 camps, and 6 parks.
**Estimated (see NES Working Paper No. 175).
***Export probably due to unknown sources and/or sampling error.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 St. Francis River	1,155,275	84.3
C-1 Clark Creek	19,845	1.5
b. Minor tributaries and immediate drainage (nonpoint load) -	173,095	12.6
c. Known municipal STP's -		
Annapolis	1,120	0.1
d. Septic tanks* -	1,435	0.1
Greenville	1,400	0.1
e. Known industrial - see discussion, pages 2-3.		
f. Direct precipitation** -	17,910	1.3
Totals	1,370,080	100.0
2. Output - A-1 St. Francis River	1,526,360	
3. Net annual N export*** -	156,280	

*Estimated based on 105 lakeside residences, 2 camps, and 5 parks.
**Estimated (see NES Working Paper No. 175).
***Export probably due to unknown sources and/or sampling error.

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
St. Francis River	14	475
Clark Creek	3	204

E. Mean Nutrient Concentration in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
B-1 West Fork Lost Creek	0.013	1.594
D-1 Big Creek	0.019	0.971
E-1 Dry Creek	0.017	0.680
F-1 Trace Creek	0.029	1.059

Nutrient levels for the above tributaries are consistent with those levels found in Clark Creek at Station C-1.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his eutrophic loading is that at which the receiving waters would become eutrophic or remain eutrophic; his oligotrophic loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between eutrophic and oligotrophic.

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Lake Wappapello	1.93
Vollenweider's eutrophic loading	1.65
Vollenweider's oligotrophic loading	0.83

V. LITERATURE REVIEWED

Missouri Department of Natural Resources (manuscript). Water Quality Management Basin Plan for Lower Mississippi River Basin. Water Quality Program, Division of Environmental Quality, Jefferson City, Missouri.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

TO

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

TRIBUTARY FLOW DATA

APPENDIX C

PHYSICAL AND CHEMICAL DATA

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APPENDIX D

TRIBUTARY DATA

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[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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75/01/11	10	45	1.272	2.990	0.224	0.010	0.014
75/02/01	13	30	1.432	1.150	0.475	0.004*	0.003
75/03/02	09	40	2.464	0.950	0.048	0.004*	0.010*
75/04/17	10	15	0.316	0.990	0.025	0.005*	0.010*
75/05/11	09	45	0.840	1.780	0.456	0.005*	0.014

* VALUE KNOWN TO BE
LESS THAN INDICATED

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DATE	TIME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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7w/13/7[illegible]	1[illegible]	71		1.7[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
7w/16/1[illegible]	1[illegible]	10		1.[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
7w/11/[illegible]	1[illegible]	15		1.[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
7w/12/[illegible]	[illegible]	50		[illegible].[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
75/11/11	11	15		1.[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
75/12/[illegible]	1[illegible]	75		1.[illegible]	1.[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	[illegible]		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	16		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	16		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	18		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/11	1[illegible]	38		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	38		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	28		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/12	13	45		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]
75/[illegible]/[illegible]	[illegible]	07		[illegible].[illegible]	[illegible].[illegible]	[illegible]	[illegible]	[illegible]

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DATE	TIME OF DAY	[illegible] FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	11 11		[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	11 45		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	04 50		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	18 39		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	17 43		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11 35		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12 07		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	09 31		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10 05		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	24 13		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	18 28		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	13 38		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	09 45		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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DATE FROM TO	TIME HR	DEPTH TO FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11	35	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	11	29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	09	34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	14	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	12	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	09	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	09	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	13	55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]
[illegible]

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF MISSOURI